

Science, Technology, Engineering, and Mathematics (STEM) Education Reform to Enhance Security of the Global Cyberspace

by Renée E. Etoty and Robert F. Erbacher

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14. ABSTRACT <p>It was about 1992 when the Internet first became publically available on the World Wide Web domain via Netscape (http://education.illinois.edu/wp/commercialism/history-of-the-internet.htm) and today has become our main way of life's dealings and interactions. Given that, we have seen digital infrastructures become the backbone of successful nations. A nation is deemed successful by their economic stability, military defense, global influence, and trade or business efforts. A nation's education system is however the most critical precondition to achieving the elements listed. For these reasons, the protection of and the continued growth of the cyberspace as an international environment is cause for a secure global cyberspace. The Internet in particular, is a vehicle the nation uses to communicate, cooperate, and conduct business dealings involving our assets and for this reason cybersecurity is a major concern. In this paper, we choose to focus on adding cybersecurity curricula to Science, Technology, Engineering, and Mathematics (STEM) education as well as combining all existing efforts into a single STEM education model. Our proposed plan, STEM–Combined (STEM–C), further suggests the incorporation of cybersecurity aspects and skills that need to be implemented early on within the nation's current STEM curricula.</p>					
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1. Introduction

The crisis in America's education system has been with us since well before the 21st century. In fact, awareness was brought to the forefront by researchers of the mid-1980's, who pointed to problematic outcomes in undergraduate Science, Technology, Engineering, and Mathematics (STEM) education in terms of declining enrollment, dropouts, and field-switching (1, 2). Since then, many educators, organizations, schools, companies, and government agencies have put their own spin on interpreting STEM and have provided their own initiatives for educating students. Regardless of these efforts, America's educational competitiveness continues to drop below the rankings compared with the rest of the world (3). For the past 30 years, America has struggled to provide critical coordination and direction for STEM education within the nation. Direct role currently lies in the hands of local education agencies, school boards, state boards, federal government, institutions of higher learning, business and industry, teacher unions, learning communities, nonprofits, and private foundations all at the same time. This is a bad thing because without a clear direction, goal, and stated benefits for STEM education students remain at a disadvantage because they do not have a true scale to compare their performance within America. With a federal education standard, more money is able to be appropriated for STEM education, which is a relief for the states who lack the funding (4). Tests would then be able to be standardized to verify accurately the country's STEM performance (4) and failure to adhere standards could result in no funding support, such as with No Child Left Behind. Recent statistics released by Condoleezza Rice and Joel I. Klein, chairs of the Council on Foreign Relations (CFR), in their independent task force number 68 (5) stated an immediate need for change in the nation's education system. The report points out that while the United States (U.S.) invests more in kindergarten through high school public education than any other developed country in the world, their students are still ill-prepared to compete with their global peers. Common rationale behind STEM education is that the nation relies on the science and engineering workforce to sustain global economic competitiveness and threatened national security (6). The article (5) expounds on the main point that America's failures in education pose five distinct threats to national security:

1. Threats to economic growth and competitiveness.
2. Threats to the physical safety of America.
3. Threats to intellectual property.
4. Threats to America's Global Awareness.
5. Threats to unity and cohesion within America.

They agree that the military has been a thriving force in protecting the nation's assets and security but argue that the military alone is no longer sufficient to guarantee the nation's security. Rice and Klein mention that today's national security is tightly linked to human capital, which is as strong or as weak as a nation's education system. In addition, recent changes in industry towards cloud computing technologies and capabilities demand needs for developing new tools that work in ensemble to handle security challenges. A cyberspace operation is a method used to combat network security threats; however, America currently lacks the properly skilled and trained workforce to carry out its demanding tasks. Simply put, there is a different set of skills needed now than there was 50 years ago and the Department of Defense (DOD), and others, require a STEM workforce for their future existence (7, 8). Detailed and recent STEM contributions of the Army are highlighted in the appendix. The existing challenge of greater global competition and current high unemployment rates (9) due to a lack of qualified candidates adds pressure to fill the void. This is a major concern for DOD.

2. Call for Action

According to the results of the 2009 Program for International Student Assessment (PISA), U.S. students ranked 14th in reading, 25th in math, and 17th in science compared to students in other developed nations (10). PISA is an international assessment that measures the performance of 15-year-old students in reading, mathematics, and science every three years. In 2010, American students finished 15th in reading, 19th in math, and 14th in science in the ranking of 31 countries by the Organization for Economic Cooperation and Development. Only one-third of eighth-grade students and barely 18% of 12th-grade students perform at or above the proficient level in science. Another alarming trend is that the top American students are foregoing careers in STEM. There are steep declines in engineering by 25%, and declines in mathematics by 19% (11).

Reasons for American student's poor performance include:

- Low value of professors and teachers (8)
- Professors and teachers lack professional development (8)
- Different skill sets that they are not prepared for (8)
- The inclusion of global competitors (8)
- Universities' approach to "weed-out" classes deters interested students (12)
- Students are underprepared for college-level math and science

- A poor education system (13)
- Aptitude being overrated as a factor in achievement (13)
- Failure to keep highly qualified STEM professionals who are attracted to teaching (13)
- Some teachers do not relate well or communicate STEM knowledge to students (13)
- Lack of resources (14)
- Benign discouragement by well-meaning adults (14)
- Active exclusion by powerful gatekeepers (14)
- Lack of attitude toward change (15)
- Appropriate funding for the education system (15)
- Fear of letting students use cyberspace (15)
- Students do not feel safe in schools (15)

As these reasons persist to grow, the student's likelihood for completing a bachelor's degree in a STEM major is greatly diminished. Examine the graphs in figure 1 where high school students over the past 16 years have failed to take computer science courses; and in figure 2 the undergraduate enrollment for computer science is low. Statistics (16) show that the completion rates for first-time college students achieving their bachelor's degree is lower in mathematics, physical sciences, and computer science than in non-science and engineering fields. See figure 3.

Project Lead the Way (PLTW) recognizes that due to high retirement rates of the "Baby Boomer," engineers today and high dropout rates of college engineering students, there is currently a void of over one million engineers in the U.S. (17). This is a huge deficit compared to America's total population of about 304 million people. PLTW is an organization that promotes STEM proficiencies using hands-on project and design-based instruction (17). Unfortunately, the crucial need for student interest in STEM will not subside anytime soon according to the U.S. Department of Labor's prediction that by 2014 there will be two million job openings in STEM fields (11). That doubles the deficit on the need of qualified candidates for the STEM job market. Taking a closer look at America's education system compared to the best performing educational systems across the world has revealed gaps. Statistics put forth by Condoleezza Rice and Joel Kline in their 2012 Council on Foreign Relations task force identified the nation's main vulnerability as the inability to produce citizens through their education system that can protect and defend national security.

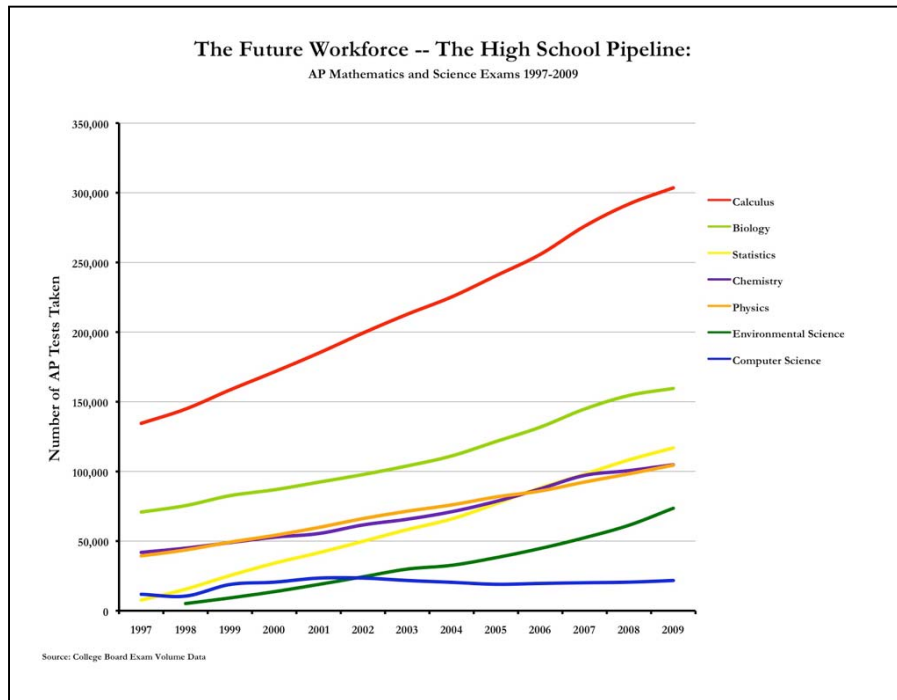


Figure 1. High school students fail to take computer science (18).

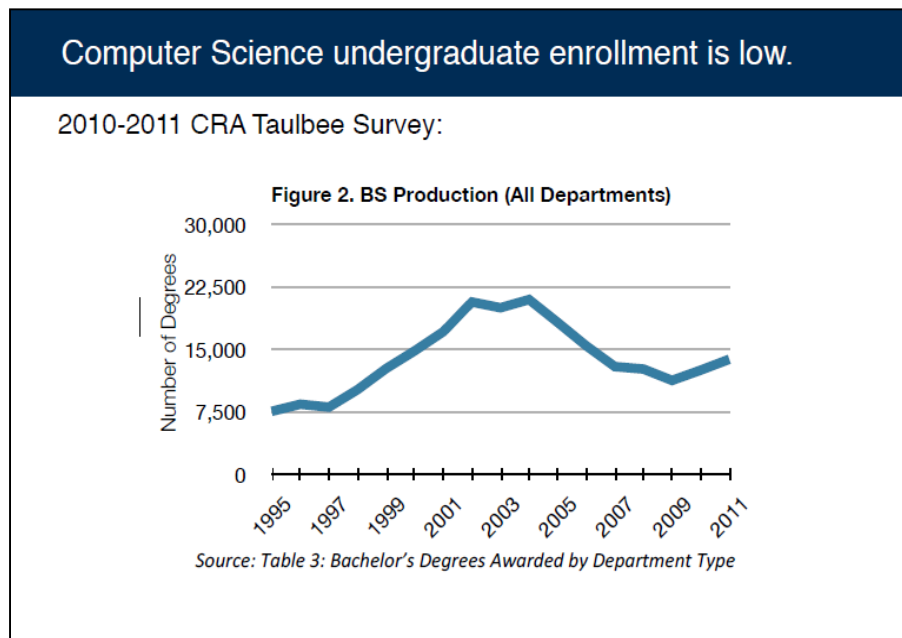


Figure 2. Computer science undergraduate enrollment is low (18).

Table 2-8

Persistence and outcome of postsecondary students beginning 4-year colleges or universities in 2004: 2009

Major in 2004	Number	Cumulative persistence outcome, 2009 (%)			
		Bachelor's	Associate's or certificate	Still enrolled	No longer enrolled
All majors	1,657,800	57.8	6.2	12.2	23.7
S&E	397,500	63.3	4.5	11.7	20.5
Agricultural/biological sciences	80,600	71.4	3.1	10.2	15.3
Physical/math/computer sciences	85,300	51.7	7.4	11.3	29.5
Engineering	107,300	60.8	4.5	14.2	20.5
Social/behavioral sciences	124,300	62.4	3.4	14.7	19.1
Non-S&E	790,900	55.2	7.3	13.0	24.5
Missing/undeclared	469,400	57.5	5.9	11.3	25.3

NOTE: Physical sciences include earth, atmospheric, and ocean sciences. Social sciences include history.

SOURCE: U.S. Department of Education, National Center for Education Statistics, 2003–04 Beginning Postsecondary Students Longitudinal Study, Second Follow-Up (BPS:04/09), <http://nces.ed.gov/datalab/index.aspx>.

Science and Engineering Indicators 2012

Figure 3. Science and engineering majors indicators in 2004 for the year 2009 (16).

3. Current U.S. STEM Status

Improving upon America's current STEM curricula involves first coining a national definition of STEM and stating its requirements and standards at the national level. This means that states and locals will have to make sure their school education systems meet the bare minimums that will be recognized nationally. Currently, there appears to be no agreed-upon definition, requirements, or standards for STEM (19). Even so, many national organizations, local groups, schools, and companies have put forth a spin on what they think is necessary when it comes to STEM and its applications of learning for American students. All of these entities are considered as U.S. educational contributors and possible stakeholders for the reformation of STEM education. See figure 4.

Some popular educational expectations among the states were initiated by the states and formalized by the National Education Association (NEA). The NEA has provided a set of standards called the Common Cores that have been adopted in America except by the following (20):

- Alaska

- Minnesota
- Nebraska
- Northern Mariana Islands
- Puerto Rico
- Texas
- Virginia



Figure 4. An illustration showing U.S. major educational contributors.

The Common Core State Standards was originally coordinated by the National Governors Association (NGA) Center for Best Practices and the Council of Chief State School Officer (CCSSO). The standards were developed in collaboration with teachers, school administrators, and experts, to provide a clear and consistent framework to prepare the American student for college and workforce (21). The Common Core State Standards are the resultant of the National Science Standards (10). State Education Reforms (SER) is an organization that draws information from the National Center of Education Statistics (NCES) to educate, promote, and

suggest fixes to the American education system. They focus on educational reform in five areas (22):

- Accountability
- Assessment and Standards
- Staff Qualifications and Development
- State Support for School Choice and Other Options
- Student Readiness and Progress through School

Other programs, such as No Child Left Behind (NCLB), promote supporting college and career-ready standards in the educational process of preparing students. Some rewarding progress and success has been made in turning around the lowest-performing schools in America (23).

Organizations like PLTW offer extensive STEM topics for middle and high schools. They have the largest pre-engineering curricula available at the secondary education level. Teachers are able to obtain free curriculum by logging in as a guest and downloading the material from PLTW (24). According to Marlene C. Scott of the Technology Education for Children Council, “STEM is more than just math equations, lab reports, and spreadsheets. It is about exploring subjects that can lead to exciting careers, better equipped students, and making smarter individuals.”

3.1 Current STEM Education Curriculum in Preschools

Based on our research there is currently no existing STEM education curriculum for the preschool level. However there are many supporters who encourage and push for early childhood STEM education. Change the Equation, a nonprofit initiative for learning math and science, believes that the best way to ensure a future pipeline of STEM workers is to foster the skills earlier in youth (25). Dean Kamen is another advocate for early childhood STEM education and has been working with kids since 1989 with the help of the LEGO* Group and their educational products to create excitement and learning (26). In fact, research done by Clayton Early Learning (27) shows that children are more competent in math and science than their teachers and parents believe; that gender and socioeconomic gaps related to STEM develop in the preschool years; and that teaching STEM at these early ages does not require teachers to have all the answers but to know the questions. We too support the push to incorporate STEM education in the early childhood years; it makes sense with the way current technologies have changed this new generation’s way of life.

*LEGO is a registered trademark of the LEGO Group.

3.2 Current STEM Education Curriculum in Elementary Schools

These are the basic known standards that promote STEM education at the elementary school level (28):

- Provides the introductory and foundational STEM courses that lead to success in challenging and applied courses in secondary grades
- Introduces awareness of STEM fields and occupations
- Provides standards-based, structured inquiry-based and real-world problem-based learning that interconnects STEM subjects
- Stimulates student interest in “wanting to” rather than “having to” take further STEM-related courses
- Bridges and connects in-school and out-of-school learning opportunities

3.3 Current STEM Education Curriculum in Middle Schools

These are the basic known standards that promote STEM education at the middle school level (28):

- Introduces an interdisciplinary program of study consisting of rigorous and challenging courses
- Continues to provide standards-based, structured inquiry-based and real-world problem-based learning that interconnects STEM-related subjects
- Bridges and connects in-school and out-of-school learning opportunities
- Increases student awareness of STEM fields and occupations, especially for underrepresented populations, minorities
- Increases student awareness of the academic requirements for STEM fields and occupations
- Exploration of STEM-related careers, especially for underrepresented populations

3.4 Current STEM Education Curriculum in High Schools

These are the basic known standards that promote STEM education at the high school level (28):

- Provides a challenging and rigorous program of study focusing on the application of STEM subjects
- Offers courses for preparation in STEM fields and occupations
- Bridges and connects in-school and out-of-school learning opportunities

- Provides opportunities for student exploration of STEM-related fields and careers, especially for underrepresented populations, minorities
- Prepares students for successful postsecondary employment, education, or both

3.5 Current STEM Education Curriculum in Colleges and Universities

Most colleges and universities that incorporate science- or technology-specific curricula develop their own standards that are heavily influenced by the requirements of closely affiliated companies who have programs with the schools and/or hire from their pool of students. Therefore, no real STEM standards exist at the tertiary and beyond levels of education. Within the last 10 years, some colleges and universities that meet the National Security Agency's (NSA's) Central Security Service guidelines (29) have been designated as a Center of Academic Excellence in Cyber Operations.

4. Science, Technology, Engineering, and Mathematics–Combined (STEM–C) Plan

4.1 STEM–C Overview

We propose a plan, STEM–C, where we first strengthen the STEM education of the U.S. at the national level by looking at the nation's current STEM standards, programs, and curriculum to examine areas of improvement to close the gap toward better preparedness and understanding of related cyberspace topics. We then integrate crucial skills needed to be successful in any related STEM job that yields to the security of the global cyberspace. Lastly, we suggest that the U.S. takes the lead on promoting an international effort to standardize education. Our STEM–C reformation plan benefits the community by:

- Enhancing the many U.S. STEM initiatives by combining them under a unified umbrella
- Provides implemented direction and progression into career paths for cybersecurity workforce candidates
- Assists with closing the gap of vacant cybersecurity and STEM positions in the U.S. job market
- Provides a developed plan to standardize STEM education in the U.S. based on the many existing efforts

Our STEM–C plan builds upon other existing ideas, initiatives, plans, programs, proposals, and task forces. Our major contributions are:

- Emphasis to add cyber operations topics to the STEM education pipeline

- Recommendation to widen the STEM education pipeline to include early childhood education
- Recommendation to combine all existing STEM ideas, initiatives, plans, programs, proposals, and tasks forces into one unified STEM education model
- Recommendation to standardize STEM education from a top-down approach in the U.S.
- Recommendation to have the U.S. use this newly unified STEM model as a blueprint toward international STEM education standardization.

4.2 STEM–C Methodology

The first step was to examine what was already out there in existence for STEM initiatives, programs, proposals, plans, and standards. We realized that there are most likely thousands of such entities created and since the certainty of finding all of them is impossible, we then approached the examination from a high level. Our examination covers possible stakeholders and persons of interest concerned with the nation’s STEM education. We call these individuals the U.S. educational contributors. We then created a model of three tiers for organizational purposes and ease of communication among them for policymaking. The three tiers are the local level, the state level, and the national level. See figure 5.

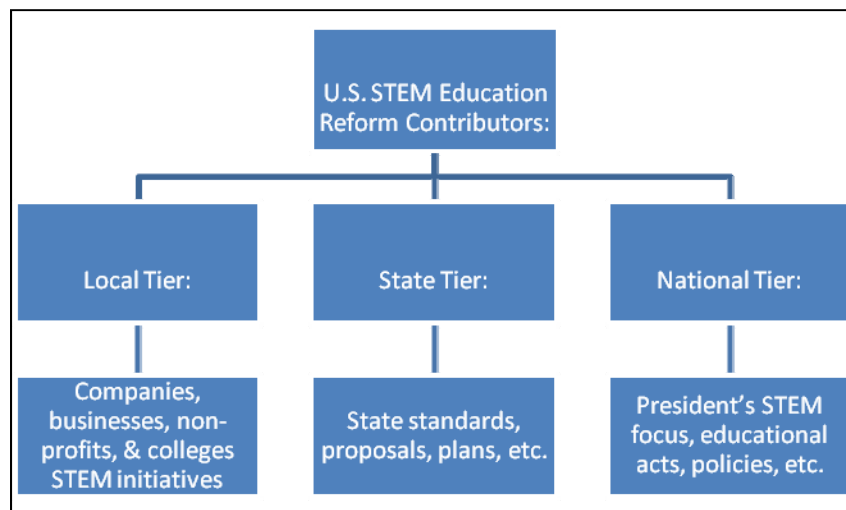


Figure 5. U.S. educational contributors’ tier breakdown model.

The second step is to execute Phase I of the STEM–C plan. Phase I focuses on the unification of STEM education in America. Once the same STEM material is taught throughout the nation, we will then produce competent candidates who can handle the known and unknown cyber operations concerning the security of the global cyberspace. We suggest that the following steps be incorporated to achieve the aforementioned outcomes:

Goal #1: To increase qualified STEM professionals and cybersecurity specialists. See figure 6.

Objective 1: To reform STEM education in the U.S.

Step 1. Invite and encourage stakeholders of the U.S. education system to come together and partake in the nation's reformation of its STEM education system.

Step 2. Review and examine all existing *standards* to highlight the similarities and differences on the local, state, and national tiers.

Step 3. Review and examine all existing *STEM programs* and initiatives to highlight the similarities and differences on the local, state, and national tiers.

Step 4. Review and examine all existing initiatives for STEM education reform to highlight the similarities and differences on the local, state, and national tiers.

Step 5. Combine the similarity and difference results from steps 2–4.

Step 6. Incorporate all of the similarities from the combined inventory into a single STEM education model.

Step 7. Incorporate all of the differences into the new single STEM education model.

Step 8. Examine the newly built STEM education model that has resulted from the existing STEM emphasis within the three tiers of educational contributors in our nation to identify further loopholes, areas of weakness, and areas of improvement.

Step 9. Incorporate specific topics and crucial skills needed to be successful in cyber operations and network security related jobs much early on into the new STEM education model pipeline. Subjects such as computer science, information assurance, internet security, information technology, forensic science, and software assurance are necessary for the pipeline.

Step 10. Incorporate critical thinking skills, analytical skills, technical writing skills, and team building skills early on in the new STEM education model pipeline.

Step 11. Incorporate personalization, mentorship, training, internships, and co-op (cooperative) education opportunities beginning at the 8th-grade middle school level of education into the new STEM education model pipeline.

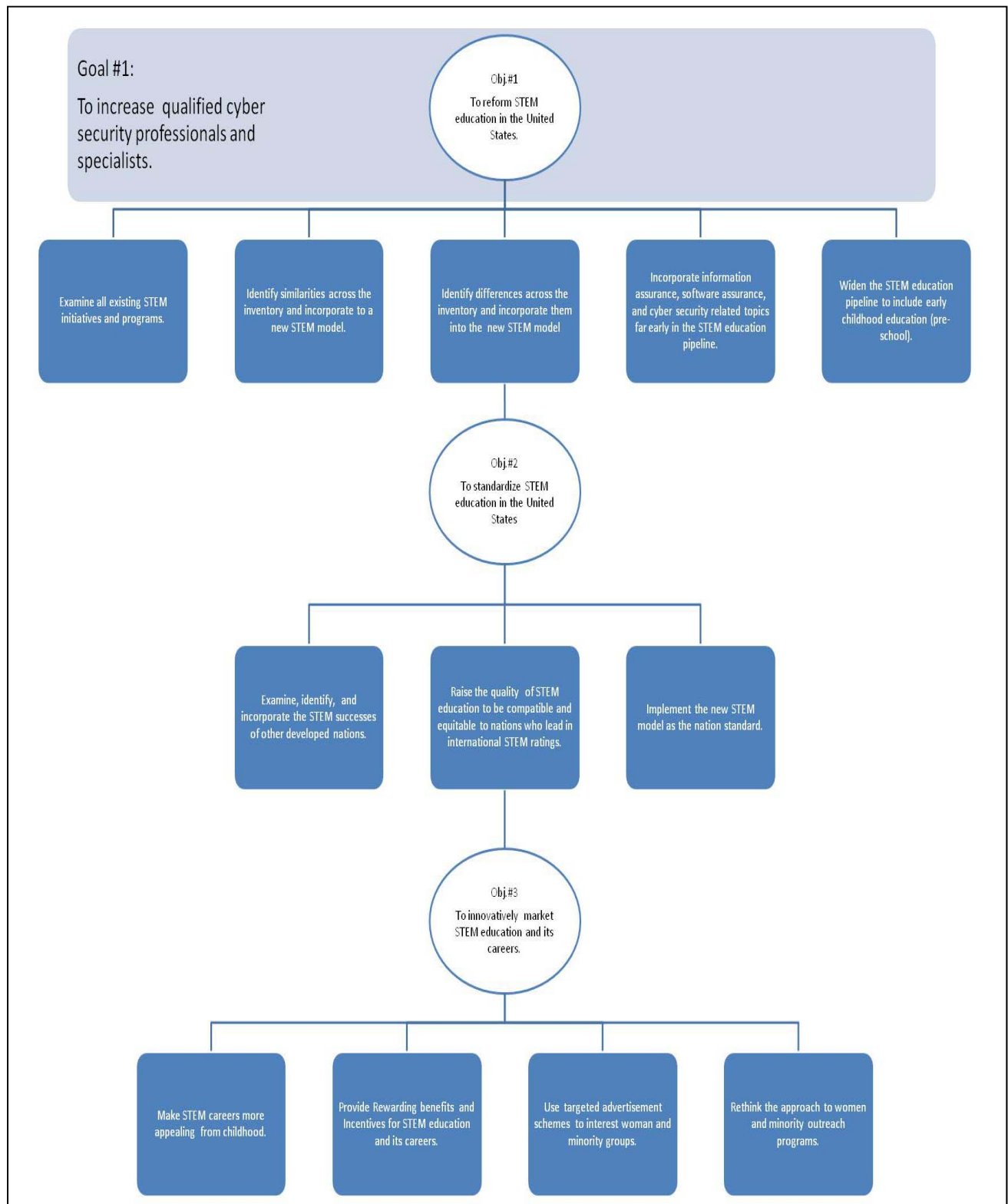


Figure 6. Goal #1 has three objectives with points on how they will be achieved.

Objective 2: To standardize STEM education in the U.S.

- Step 1. Raise the level of quality in STEM education to be more than compatible and equitable to nations who lead in international STEM ratings.
- Step 2. Incorporate those findings of Step 1 into the new American STEM education model.
- Step 3. Have the U.S. Department of Education's National Technical Advisory Council (NTAC) implement the new STEM education model.
- Step 4. Top-down implementation of the new STEM education model as the nation's standard instead of the current bottom-up approach.

Objective 3 To innovatively market STEM education and its careers.

- Step 1. Make STEM careers more appealing from childhood.
- Step 2. Provide rewarding benefits and incentives for STEM education and its careers.
- Step 3. Rethink the approach to women and minority outreach programs.
- Step 4. Understand the culture of each targeted minority group and their historical hurdles and then consider how to encourage them to finish STEM education and to retain their progression in STEM careers.
- Step 5. Use targeted advertisement schemes to interest women and minority groups in efforts to bridge the gap.

Goal #2 To equip the candidates with the best skills and tools for the protection and maintenance of an ever-growing cyberspace. See figure 7.

Objective 1: To develop and incorporate a cyberspace operations competency model.

- Step 1. Identify knowledge areas and competencies.
- Step 2. Identify competency attributes of effectiveness.
- Step 3. Identify and develop competency designations.
- Step 4. Incorporate Steps 1–3 into a model for an assessment and career progression standard.

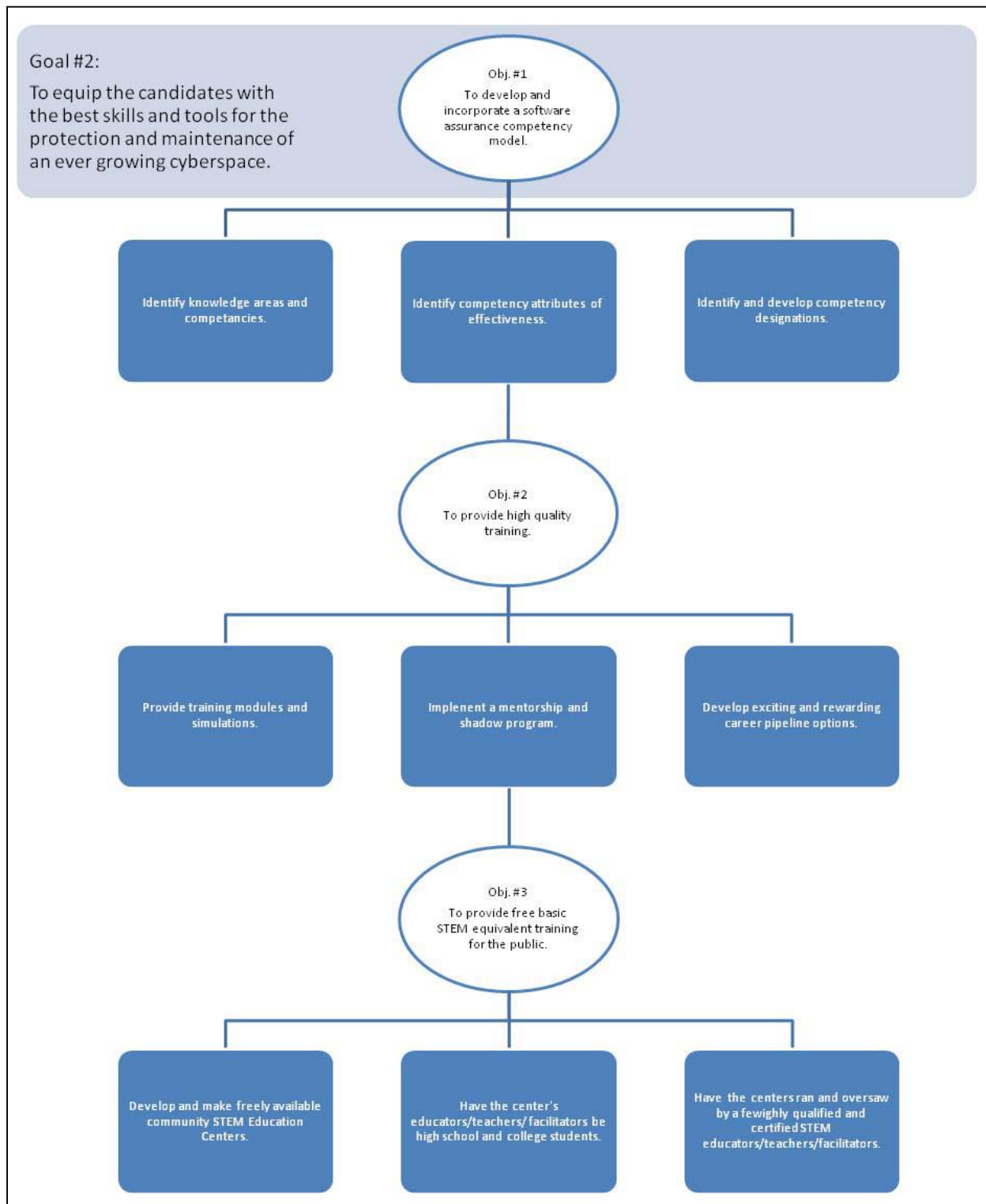


Figure 7. Goal#2 has three objectives with its points on how they will be achieved.

Objective 2: To provide high-quality training.

- Step 1. Provide training classes, modules, and simulations.
- Step 2. Implement mentorship and shadow programs.
- Step 3. Develop exciting and rewarding career pipeline options.
- Step 4. Develop and implement fast-track career/training paths for cyber operations and STEM careers.

Objective 3: To provide free basic STEM equivalent training for the public.

- Step 1. Develop and make freely available to the Community STEM Education Centers.
- Step 2. The community development centers should focus on current computer skills, technical writing skills, presentation skills, research skills, and STEM-related subjects.
- Step 3. Have the centers run and overseen by a few highly qualified and certified STEM educators/teachers/facilitators. They should train student volunteers and should receive a grant or reasonable pay for service and running the facility.
- Step 4. Have the center's educators/teachers/facilitators be high school and college students. They can volunteer for school credits while teaching the public for free.
- Step 5. Provide free online and walk-in options for trainings.

Goal #3: To decrease the nation's lagging gap in international STEM education performance when compared with other developed nations. See figure 8.

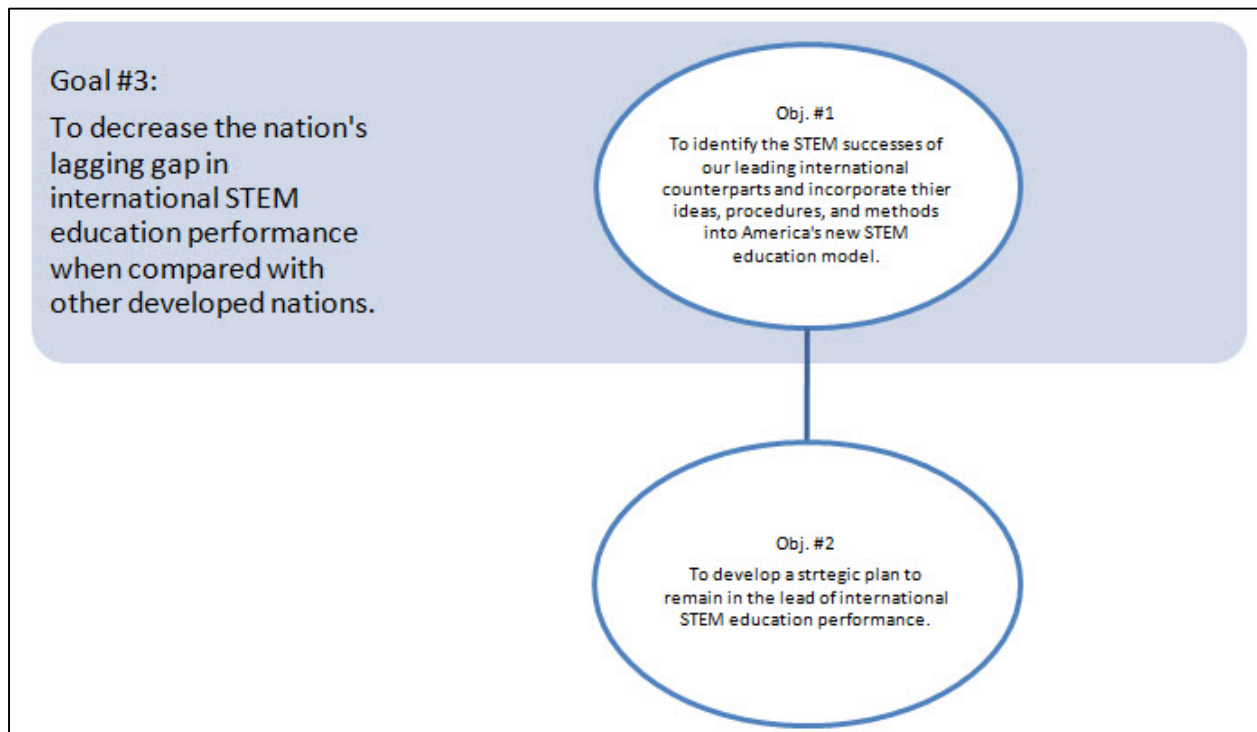


Figure 8. Goal#3 and its two objectives.

Objective 1: To identify the STEM successes of our leading international counterparts and incorporate their ideas, procedures, and methods into America's new STEM education model.

- Step 1. Identify the differences in other country's STEM education pipelines.
- Step 2. Adjust the American STEM education pipeline to reflect the same age levels that our counterparts are exposed to particular STEM topics.
- Step 3. Based on findings for Step 2, push the age levels back a few years for the American STEM education pipeline. This will give the U.S. a leading edge for introducing STEM topics and will produce a higher rate of the individuals capturing the materials.
- Step 4. Incorporate Steps 1–3 into the American new STEM education model for all school levels (early childhood, preschool, elementary, middle, high, and college). This will close the U.S. gap and increase its overall international STEM rating in the world.

Objective 2: To develop a strategic plan to remain in the lead of international STEM education performance.

- Step 1. Continue to build America's people by adhering to the standardized implementation of the new STEM education model.
- Step 2. Provide rewarding incentives and benefits to encourage the states and related parties supporting STEM education to freely accept the top-down approach of standardization of STEM education in America. Not forcing a mandate on the state and local tiers promotes willing cooperation and a faster overall turnaround recovery rate for the vacancies in the STEM and cyber operations workforce.
- Step 3. Develop and incorporate a plan for foreign and immigrant students who live and attend school in America. The plan should provide benefits and incentives for them to remain in America and work in STEM fields after the completion of tertiary education as opposed to going home to their native country and using their invested skills there.

The third step of STEM-C is to use this new STEM education model as a blueprint for the standardization of STEM education at an international level. There is some time before this can effectively happen but we are already looking at ways to make this effort a smooth transition benefiting both the U.S. and its global partners. When the time is right, America will have a successful STEM education pipeline sustained with growth for several years. As a result there will be a significant increase in cyber operations personnel, a significant increase in overall STEM personnel, and a closed gap in international STEM performance compared with other developed counterparts. See figure 9. America will regain the global lead of the science and technology industry and the international STEM performance ratings. This third step of the STEM-C is currently our future work and is still being researched for development. We welcome community input.

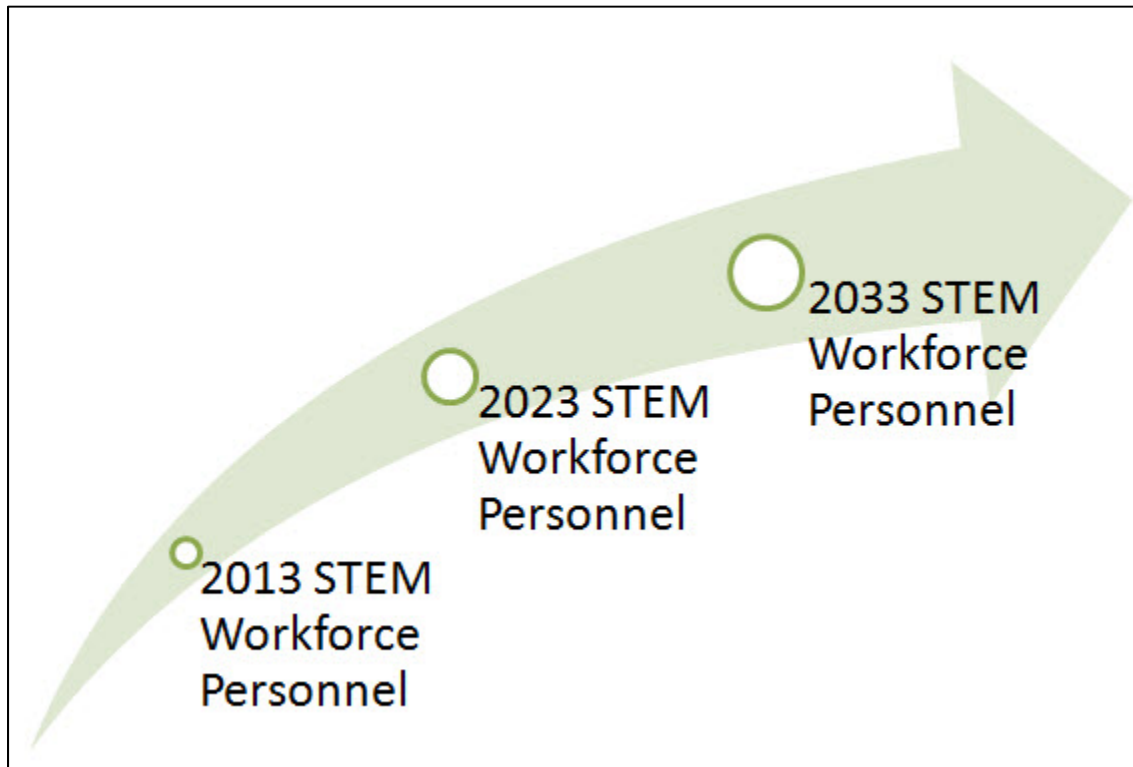


Figure 9. STEM workforce personnel expected growth overview.

5. Overcoming Challenges

It is with people and ideas that difficult challenges are overcome. We know and understand that nothing can be fixed overnight but we must start here. Certain communities already realize the urgency for a plan such as this and we cannot afford to wait any longer, the protection of America's assets is at stake. Additionally, it is critical to begin brainstorming solutions to some of the major challenges that affect aspects of a unified STEM education system. We anticipate some to be:

- Community Center Funding
- Coordination for International Students in U.S. (foreign and immigrant students)
- Early Childhood Education
- Education Funding
- Legislative Drafts and Approvals (national/local)
- Minority Outreach

- No Budgets
- No Child Left Behind Act
- Shrinking Budgets
- Stakeholders Cooperation
- STEM Afterschool Programs
- Teacher Bonuses and Incentives
- Teacher's Professional Pay
- Teacher Quality
- Transportation (afterschool programs/co-ops/internships/community centers)

Even with these challenges, we strongly endorse our STEM-C plan for the U.S. If nothing is done, we can assure that the U.S. will be an observer watching the rest of the world as our global competitors lead with better education, stronger strategic plans, flourishing economies, powerful militaries, unified peoples, and a respectable influence on the rest of the world.

6. Conclusions

Improving and standardizing STEM education across America is critical to increasing qualified STEM professionals, equipping them with the best skill sets, and ensuring that America remains a competitive leader in international STEM performance. Increased public awareness, proper training, reformation of STEM education, and unified top-down action are vital to addressing this crisis. The 21st century workforce, especially cyber operations and STEM fields have an increasing demand for literate candidates. Our proposed STEM-C plan is essential to first upgrading and unifying STEM education in America. Once America is back on track with an implemented STEM education standard, it can then begin to generate the desired and needed workforce that is capable of handling related jobs for maintenance and protection of the global cyberspace. America will then be able to close the gap in international STEM performance and lead the world again. Other developing countries of the world should look to the U.S. as an educational, economic, military, and diplomatic leader. It is with positive global leadership that international STEM education efforts can be made that would secure the future of the global cyberspace.

7. References

1. Seymour, E.; Hewitt, N. M. *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder, CO: Westview Press, 1997.
2. Seymour, E. Tracking the Process of Change in U.S. Undergraduate Education in Science, Mathematics, Engineering, and Technology. *Science Education* (86): 79–105, 2001.
3. How Does the U.S. Compare to Other Countries in STEM Education? Level Playing Field Institute Web Site. <<http://www.lphi.org/how-does-us-compare-other-countries-stem-education>> (accessed October 21, 2013).
4. More States Defying Federal Gov't on Education Law. Fox News. <<http://www.foxnews.com/us/2011/07/21/more-states-defying-federal-govt-on-education-law/>> (accessed October 22, 2013), July 21, 2011.
5. Klein, J. I.; Rice, C. U.S. Education Reform and National Security. Council on Foreign Relations Press. <<http://www.cfr.org/united-states/U.S.-education-reform-national-security/p27618>> (accessed January 22, 2013), 2012.
6. Ahearn, R. J. Globalization, Worker Insecurity, and Policy Approaches. Library of Congress Washington DC Congressional Research Service, July 2007.
7. Cardno, C.A. Civil Engineering the Magazine of the American Society of Civil Engineers. <<http://www.asce.org/CEMagazine/Article.aspx?id=25769808017#.UmVp-hC2Y40>> (accessed on October 21, 2013).
8. Shure, N. Stepping it Up in STEM Education Q and A With David E. Drew. Metro. <<http://www.metro.us/newyork/lifestyle/education/2013/03/25/stepping-it-up-in-stem-education-q-and-a-with-david-e-drew/>> (accessed October 21, 2013), March 25, 2013.
9. Bennett, W.J. U.S. Lag in Science, Math a Disaster in the Making. CNN. <<http://www.cnn.com/2012/02/09/opinion/bennett-stem-education/>> (accessed October 21, 2013), February 9, 2012.
10. Brenner, D. Resources STEM Topics in Elementary Education. *Technology and Children, A Journal for Elementary School Technology Education*, September 2009.
11. College Board Exam Volume Data. <<http://www.acm.org/public-policy/AP%20Test%20Graph%202009.jpg>> (accessed January 22, 2013).
12. Center for Digital Education. Transforming STRM Learning Through Technology in Elementary School. *Center for Digital Education Publication*, pp. 2–6, March 31, 2011.

13. Drew, D. The Five Misconceptions About Teaching Math and Science –American Education Has Not Declined and Other Surprising Truths. Future Tense.
<http://www.slate.com/articles/technology/future_tense/2012/06/science_education_myths_that_keep_us_from_fixing_the_system_.html> (accessed October 29, 2013), June 19, 2012.
14. Lee, D. N. A Dream Deferred – How Access to STEM is Denied to Many Students Before They Get in the Door Good. Scientific American.
<<http://blogs.scientificamerican.com/urban-scientist/2013/01/24/a-dream-deferred-how-access-to-stem-is-denied-to-many-students-before-they-get-in-the-door-good/>> (accessed October 29, 2013), January 24, 2013.
15. Edwards, D. 12 Most Common Barriers to Education. 12 Most Web Site.
<<http://12most.com/2011/11/21/12-common-barriers-education-reform/>> (accessed October 29, 2013), November 21, 2011.
16. <<http://www.nsf.gov/statistics/seind12/c2/c2s2.htm#s3>>. Table 2–8 (accessed October 29, 2013).
17. Center for Digital Education. Transforming STRM Learning Through Technology in Elementary School. *Center for Digital Education Publication*, pp. 2–6, March 31, 2011.
18. Shores, K. California Department of Education. Last Updated: May 2, 2014.
<<http://www.cde.ca.gov/pd/ca/sc/stemintrod.asp>> (accessed January 22, 2013).
19. National Education Association. Science, Technology, Engineering, and Mathematics (STEM). National Education Association Web Site. <<http://www.nea.org/home/stem.html>> (accessed January 22, 2013).
20. National Governor’s Association (NGA). Common Core State Standards.
<<http://www.achieve.org/achieving-common-core>> (accessed January 22, 2013), 2009.
21. *Science, Technology, Engineering, and Mathematics (STEM) Information*. The California Department of Education. <<http://www.cde.ca.gov/pd/ca/sc/stemintrod.asp>> (accessed January 22, 2013), July 3, 2012.
22. Lewin, T. Many States Adopt National Standards for Their Schools. New York Times.
<http://www.nytimes.com/2010/07/21/education/21standards.html?_r=0> (accessed on February 6, 2013), July 21, 2010.
23. Mathis, W. J. The “Common Core” Standards Initiative: An Effective Reform Tool. *Boulder and Tempe: Education and the Public Interest Center & Education Policy Research Unit*. Retrieved July, 29, 2010.
24. U.S. Department of Education’s Web Site.
<http://www2.ed.gov/policy/elsec/leg/blueprint/publication_pg4.html#part4> (accessed February 6, 2013), Last Updated: May 27, 2011.

25. Chesloff, J.D. Education Week.
<<http://www.edweek.org/ew/articles/2013/03/06/23chesloff.h32.html?tkn=MTLFSlaDIDPOCYpwLiKGXu88H0U33hZkju%2F1&intc=es>> (accessed October 22, 2013), March 5, 2013.
26. Silbey, M. How to Start a STEM Program for 6 Year Olds? Try Legos. SmartPlanet Web Site. <<http://www.smartplanet.com/blog/report/how-to-start-a-stem-program-for-6-year-olds-try-legos/3060>> (accessed October 22, 2013), September 28, 2013.
27. Soden, R. Curious Minds – Three Things to Remember About STEM in Early Childhood Education. Clayton Early Learning Web Site.
<<http://www.claytonearlylearning.org/blog/?p=541>> (accessed October 22, 2013), December 3, 2010.
28. McLaughlin, C. *What Works Open Tech Lab?* Technology and Children – A Journal for Elementary School Technology Education. pp. 18, September 2009.
29. Chiesa, A.; Tromer, E. Welcome to the National Security Agency – NSA/CSS.
< <http://www.nsa.gov/>> (accessed October 22, 2013).

8. Bibliography

- 21st Century Challenges. Growth in Internet Users. *21st Century Challenges*,
<<http://www.21stcenturychallenges.org/60-seconds/the-exponential-growth-of-the-internet/>>
(accessed February 1, 2013).
- Bacon, T.; Tikekar, R. Experiences With Developing a Computer Security Information Assurance Curriculum. *Journal of Computing Sciences in Colleges* 18(4), 254–267, 2003.
- Boards and Commissions National Technical Advisory Council Archived Information. U.S. Department of Education. <<http://www2.ed.gov/about/bdscomm/list/ntac/index.html>> (accessed February 19, 2013), Last Updated: July 28, 2011.
- “Chapter 8 Science Education System Standards.” *National Science Education Standards*. Washington, DC: The National Academies Press, 1996.
- College Board Exam Volume Data. <<http://www.acm.org/public-policy/AP%20Test%20Graph%202009.jpg>> (accessed January 22, 2013).
- Driscoll, D. P.; Christensen, P. D. D.; Houlihan, G. T. Council of Chief State School Officers, 2004.
- Finnish National Board of Education Web Site. <<http://www.oph.fi/english/education>> (accessed February 6, 2013).
- Hands On Science Partnership Web Site. <<http://www.handsonsciencepartnership.org/making-the-case-for-stem-education-in-the-u.s>> (accessed October 18, 2013).
- History of the Internet. <<http://education.illinois.edu/wp/commercialism/history-of-the-internet.htm>> (accessed October 21, 2013).
- International Society for Technology in Education Web Site. <<https://www.iste.org/>> (accessed February 19, 2013).
- Kelly, B. The State of STEM and Jobs U.S. News and World Report.
<<http://www.usnews.com/news/articles/2012/09/21/the-state-of-stem-and-jobs>> (accessed February 19, 2013), September 21, 2012.
- Koebler, J. U.S. News and World Report. <<http://www.usnews.com/news/blogs/stem-education/2012/04/19/experts-weed-out-classes-are-killing-stem-achievement>> (accessed October 22, 2013).

- Lemke, M.; Sen, A.; Pahlke, E.; Partelow, L.; Miller, D.; Williams, T.; Kastberg, D.; Jocelyn, L. International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results From the U.S. Perspective: Highlights. U.S. Department of Education, Center for Education Statistics.
- National Center for Education Statistics. <<http://nces.ed.gov/programs/statereform/index.asp>> (accessed February 6, 2013).
- National Initiative for Cybersecurity Careers and Studies Web Site. <<http://niccs.us-cert.gov/education/education-home>> (accessed October 18, 2013).
- Obama, B. H. International Strategy for Cyberspace (2011). White House, May 16, 2011.
- Obama, B. H. National Security Strategy of the United States (2010). DIANE Publishing.
- PSB Web Site.
<http://www.pbs.org/newshour/indepth_coverage/education/no_child/federalvstate.html> (accessed October 22, 2013).
- Rothman, R. Common Standards: The Time is Now. Issue Brief. *Alliance for Excellent Education*, 2009.
- Shannon, R. The History of the Net. Retrieved February 5, 2013.
- STEM Education Coalition Web Site. <<http://www.stemedcoalition.org/>> (accessed on February 19, 2013).
- STEM Education Resource Center. PBS Teachers. <<http://www.pbs.org/teachers/stem/>> (accessed on February 19, 2013).
- Strickland, J. "How Did the Internet Start?" HowStuffWorks.com.
<http://computer.howstuffworks.com/internet/basics/internet-start.htm> (accessed February 5, 2013).
- Taylor, A. Why Finland's Unorthodox Education System is the Best in the World. Business Insider. <<http://www.businessinsider.com/finlands-education-system-best-in-world-2012-11?op=1>> (accessed February 19, 2013).
- Van Roekel, D. Leading the STEM Challenge. Huff Post Education Section.
<http://www.huffingtonpost.com/dennis-van-roekel/leading-the-stem-challeng_b_1936512.html> (accessed February 19, 2013).
- Veenstra, C. QEDNEWS, 2011.

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Appendix. The U.S. Army Research Laboratory (ARL) Interest and Science, Technology, Engineering, and Mathematics (STEM) Initiatives

ARL has made initiatives to foster and continue the incorporation and growth of STEM education based on their mission and vision within the community. Government agencies such as ARL, the Research Development and Engineering Command (RDECOM), and others who actively engage in research and development realize that both military and civilian personnel need to have a strong foundation in math, science, and engineering to understand the basis of systems needed for Soldiers. Having a well-equipped workforce enables ARL to carry out research endeavors that fulfill their mission of attaining breakthrough science, technology, and full-spectrum operations. STEM is a major agenda that the Army continues to push because the immediate and future benefits outweigh that of no action. More intuitively, the success of the Army is dependent on incoming STEM professionals.

Work done in 2012 with West Point in New York has proven successful. Dr. Dave Kashinski teaches Army cadets advanced physics with a more interesting emphasis on practical exercises. The cadets are invited to participate in internship opportunities at nearby laboratories like Picatinny Arsenal in New Jersey.¹ This U.S. Military academy partnership is enhancing STEM ties with RDECOM. Mr. Dale Ormond, RDECOM Director, mentions that it is important to get the cadets into laboratories to continue fostering the appreciation for technology, which leads to STEM degrees then STEM careers. In addition, he encourages the academies professors and military officers to work in the labs for several years and then take the experience back to the schools to teach.¹

Back in 2011, ARL collaborated with Virginia Tech and produced 11 programs to help spark student interest in STEM careers.² This was part of the Army Educational Outreach Program and the objectives for this initiative included increasing the number of graduate students earning a STEM degree to come and work for the Department of Defense. Since then, Aberdeen Proving Ground's (APG's) Experimental Support Group STEM and Education Outreach Center has developed an installation totally dedicated to STEM programs.³ The installation is located in APG Building 4508 and was recently opened in August 2013, executing their first summer programs. This great facility is an opportunity for the Army to become a national leader in STEM education outreach and a promising way to replenish future STEM professionals.

¹RDECOM's The Insider, October 2012, Issue #4. By: David McNally from RDECOM Public Affairs.

²New ARL Agreement to Virginia Tech, 11 STEM Programs Help Spark Student Interest in STEM Careers. <<http://www.arl.army.mil/www/?article=563>> (accessed on October 9, 2013).

³RDECOM's The Insider, October 2012, Issue #4. By: Dan Lafontaine from RDECOM Public Affairs.

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List of Symbols, Abbreviations, and Acronyms

ARL	U.S. Army Research Laboratory
CCSSO	Center for Best Practices and the Council of Chief State School
CERDEC	Communications Electronics Research Development and Engineering Center
CFR	Council on Foreign Relations
DOD	Department of Defense
NEA	National Education Association
NCES	National Center of Education Statistics
NCLB	No Child Left Behind
NGA	National Governors Association
NSA	National Security Agency
NTAC	National Technical Advisory Council
PISA	Program for International Student Assessment
PLTW	Project Lead the Way
RDECOM	Research Development and Engineering Command
SER	State Education Reforms
STEM	Science, Technology, Engineering, and Mathematics
STEM–C	Science, Technology, Engineering, and Mathematics–Combined
U.S.	United States

1 DEFENSE TECHNICAL
(PDF) INFORMATION CTR
DTIC OCA

2 DIRECTOR
(PDF) US ARMY RSRCH LAB
RDRL CIO LL
IMAL HRA MAIL & RECORDS MGMT

1 GOVT PRINTG OFC
(PDF) A MALHOTRA

1 US ARMY RSRCH LAB
(PDF) ATTN RDRL CIN D
R ETOTY